PROGRAMMED INSTRUCTION

RESONANT CAVITIES

CNTT-M691 PAT

Naval Technical Training Command

For Training Purposes Only

OBJECTIVES

The student will:

1. List the two general types of resonant cavities. (1-2)
2. State the definition of the dominant mode of a resonant cavity. (3)
3. Label the electric field and the magnetic field in a rectangular and a cylindrical cavity. (5)
4. Match types of cavities with their dominant modes. (8-9)
5. State the primary advantage of a resonant cavity. (15)
6. State three principal methods of tuning resonant cavities. (16-18)
7. State four principal methods of exciting a resonant cavity. (20-21)
8. State three principal methods of removing power from a resonant cavity. (24)
9. Match reentrant resonant cavity characteristics with their descriptions. (27)
10. Select two primary uses of resonant cavities. (30-31)

SUGGESTED READING TIME 34 MINUTES

consists of a physical coil and a capacitor that are connected in parallel. To increase the resonant frequency, the value of inductance or capacitance must be reduced.

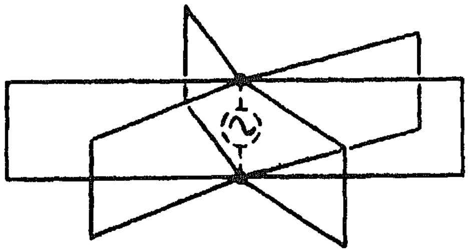
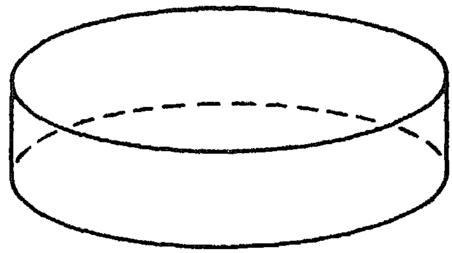
$$f_o = \frac{1}{2\pi\sqrt{LC}}$$

When the value of inductance or capacitance is reduced, the physical size of the respective component is reduced, which leads to low current-handling capacity and low breakdown voltage.

Just as waveguides are used to overcome high-frequency difficulties encountered in ordinary transmission lines, resonant cavities are used to provide effective high-frequency resonant circuits. Resonant cavities are used in waveguide and coaxial systems and behave according to waveguide theory.

1. There are many variations of the resonant cavity, but only two general types--the cylindrical and the rectangular. The cylindrical type is a closed metal container. It is made up of an infinite number of quarter-wavelength shorted stubs connected in parallel.

Figure A below illustrates several parallel shorted stubs that are cut to be resonant at the desired frequency.

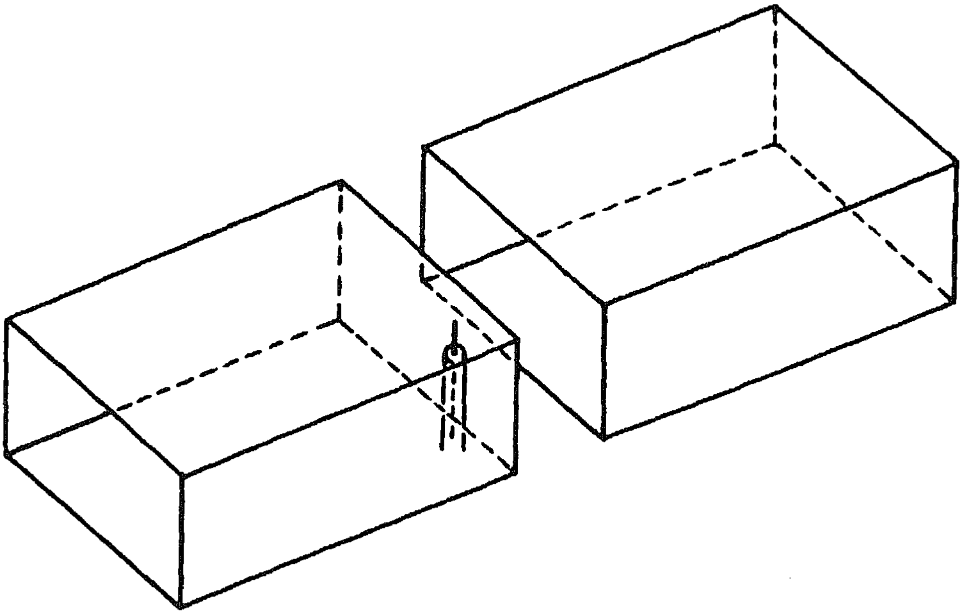
A B

When additional shorted stubs are added in parallel, the assembly eventually becomes a closed resonant cylinder, as shown in figure B. This cylinder, called a cylindrical resonant cavity, has a radius of a quarter-wavelength or a diameter of a half-wavelength of the resonant frequency.

An infinite number of quarter-wavelength shorted stubs connected in parallel form a

______________________ resonant cavity.

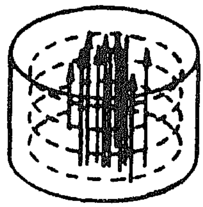
1/4-wavelength sections of shorted waveguide, as shown below.



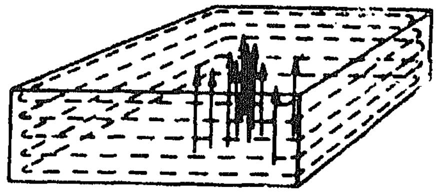
The two sections of shorted waveguide are brought together at the open ends, and a signal is introduced at the junction. The introduced signal travels toward the shorted ends and is reflected back toward the junction. The reflected wave is shifted 180° because of the shorted end, and since a distance of a half-wavelength is involved (1/4 λ + 1/4 λ), the signal returns to t ie junction in phase with the initial signal. This in-phase condition results in oscillations; thus, it becomes a resonant circuit.

	2. (Continued) The two general types of resonant cavities are ______________ and ______________.
cylindrical rectangular	3. The dominant mode of a resonant cavity is the lowest resonant frequency associated with the cavity. As in waveguides, it is possible for many different field configurations, or modes, to exist in a cavity. Associated with each such mode is a resonant frequency determined by cavity dimensions and field configurations. It is therefore possible for a resonant cavity to have an infinite number of resonant frequencies. The dominant mode of a resonant cavity is the lowest ______________ ______________ associated with the cavity.
resonant frequency	4. Select the two general types of resonant cavities. a. Spherical. b. Rectangular. c. Square. d. Cylindrical. e. Parabolic. f. Hyperbolic.

5. Although there exist an infinite number of possible modes in a cavity, the orientation of the electric and magnetic fields is more easily explained for the dominant mode. Figures A and B below illustrate the field configurations for the dominant mode of the circular and the rectangular cavity, respectively.



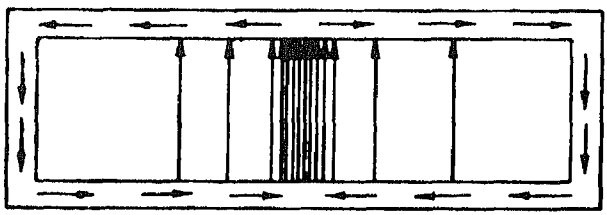
A



B

Electric field →

Magnetic field - - - →

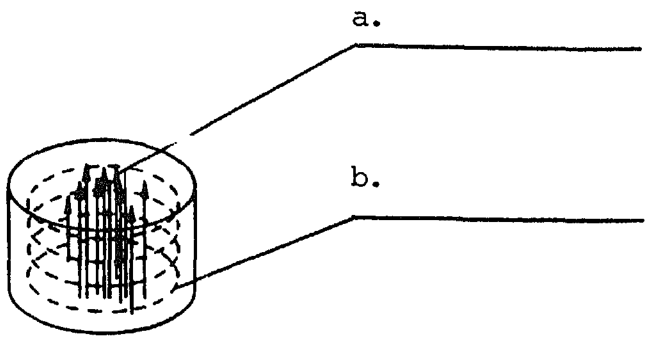


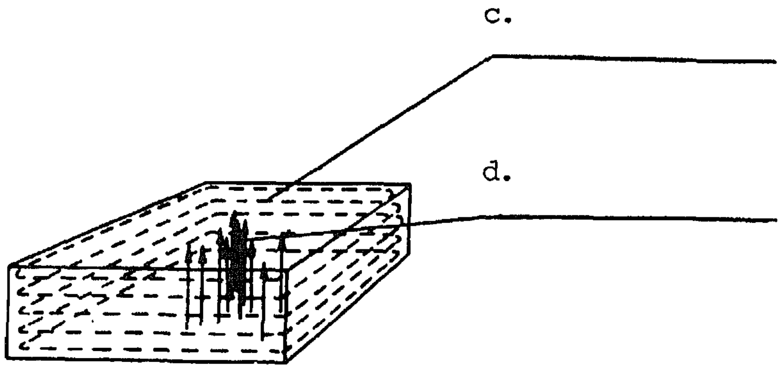
C

The cross-sectional view in figure C above illustrates that the voltage, represented by E-lines, exists between the top and the bottom of the cavity. Also illustrated is the current flowing in a thin layer on the surface of the cavity, caused by skin effect. The magnetic field, or H-field, is strongest where the current is at a maximum. The

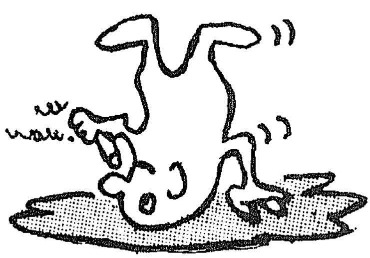
strongest H-field is at the vertical wall of the cylinder and diminishes toward the center, where the current is zero. The E-field is maximum at the center and decreases to zero at the edge, where the vertical wall is a short circuit to the voltage.

Label the electric field and the magnetic field on each of the two cavities shown below.



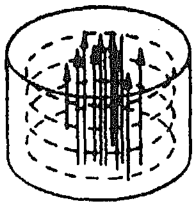


a. Electric b. Magnetic c. Magnetic d. Electric	resonant cavity. a. The highest resonant frequency associated with the cavity. b. The resonant frequency yielding the greatest power gain. c. The average resonant frequency of the cavity. d. The lowest resonant frequency associated with the cavity.
d.	7. List the two general types of resonant cavities. (1) (2)



Cylindrical.

numbering system that is used with waveguides, except that a third subscript is used to indicate the number of patterns of the transverse field along the longitudinal axis (length) of the cavity. The dominant mode of a cylindrical cavity is TM_{010}. The fields corresponding to the dominant mode of a cavity are shown below.



The first two subscripts are the same as those for a section of a cylindrical waveguide, TM_{01}. This indicates:

a. The magnetic field is perpendicular to the longitudinal axis.

b. There is no variation of the magnetic field around the circumference.

c. A half-wavelength pattern exists across the diameter of the cavity.

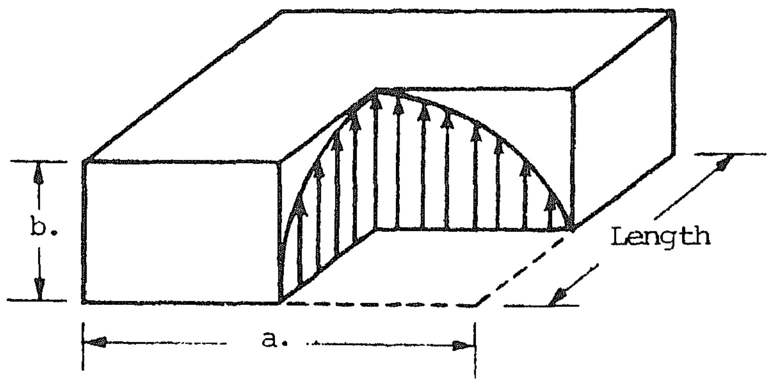
The third subscript is zero, which indicates that there is no variation along the longitudinal axis.

The dominant mode for a cylindrical cavity is

TM___.

M_{010}

9. The dominant mode of a rectangular cavity is TE_{101}. The electric field existing in the rectangular cavity is shown below.



The first two subscripts are the same as those for a section of rectangular waveguide. This indicates:

a. The electric field is transverse (perpendicular) to the longitudinal axis (length).

b. There is one half-wave variation in the wide dimension.

c. There are no half-wave variations in the narrow dimension.

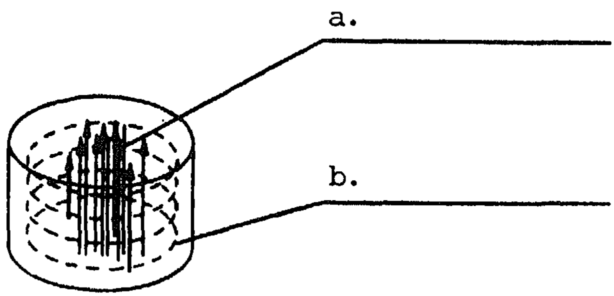
The third subscript indicates that there is one half-wave variation along the longitudinal axis.

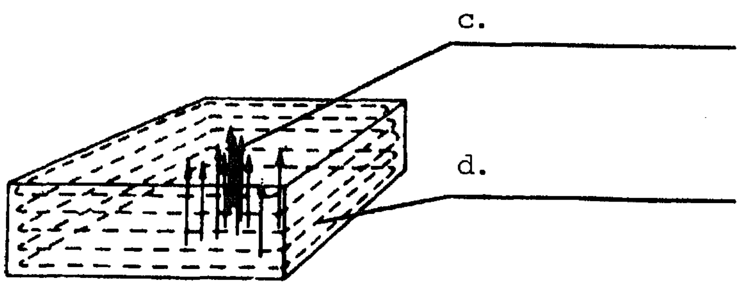
A	B
_____ (1) Rectangular.	a. TE_{100}.
_____ (2) Cylindrical.	b. TM_{111}.
	c. TM_{010}.
	d. TE_{101}.

(1) d.

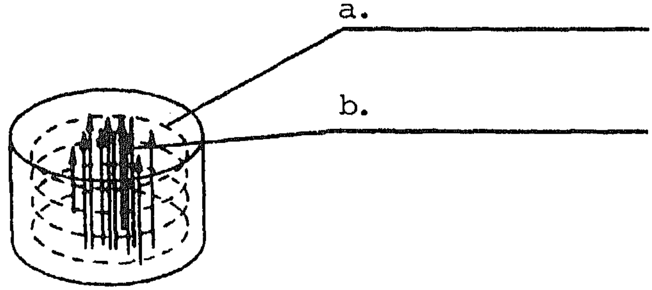
(2) c.

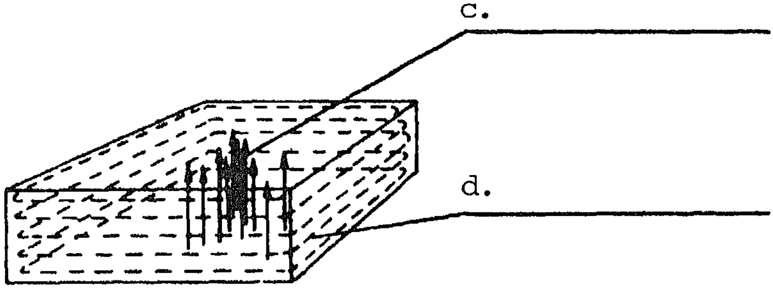
10. Label the electric field and the magnetic field on each of the two resonant cavities shown below.





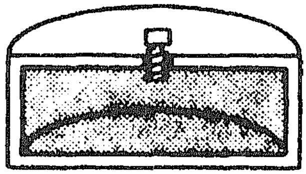
a. Electric b. Magnetic c. Electric d. Magnetic	11. State the definition of the dominant mode of a resonant cavity.
The lowest resonant frequency associated with the cavity.	12. Match each type of resonant cavity listed in colu A with its dominant mode listed in column B. A: _____ (1) Rectangular. _____ (2) Cylindrical. B: a. TM_{111}. b. TE_{100}. c. TE_{101}. d. TM_{010}.
(1) c. (2) d.	13. Label the electric field and the magnetic field o each of the two resonant cavities shown below.





b. Electric c. Electric d. Magnetic	A with its dominant mode listed in column B. A _____ (1) Rectangular. _____ (2) Cylindrical. B a. TE_{100}. b. TM_{111}. c. TM_{010}. d. TE_{101}.
(1) d. (2) c.	15. The primary advantage of a resonant cavity is its extremely high Q. A resonant cavity displays the same resonant characteristics as a tuned circuit composed of a coil and a capacitor. In the cavity, there are a large number of current paths. This means that the resistance of the cavity to current flow is very low and that the Q of the resonant circuit is very high. While it is difficult to attain a Q of several hundred in a coil of wire, it is fairly easy to construct a resonant cavity with a Q of many thousands. The primary advantage of a cavity resonator is its extremely __________ Q.

the screw method involves placing a screw into the top of the cavity, which makes a small reduction in the distance from the top to the bottom of the cavity.



Decreasing the distance (dielectric thickness) yields an increase in capacitance, as described by the formula

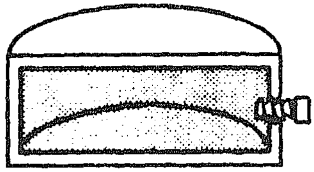
$$C = \frac{ka}{d} \qquad (1)$$

Also,

$$f_o = \frac{1}{2\pi\sqrt{LC}} \qquad (2)$$

From equation (2), it can be seen that the resonant frequency, f_o, decreases as the capacitance, C, increases.

Increasing the distance that the screw is inserted into the cavity results in a/an ______ (increase/decrease) in the resonant frequency.



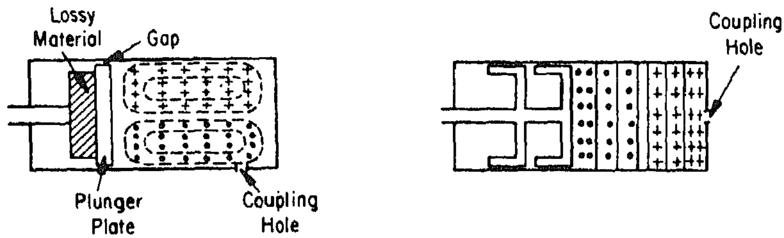
Since the magnetic flux lines are then forced to go around the slug, the lengths of the flux lines are increased. The subsequent decrease in effective inductance results in an increase in the resonant frequency.

In slug tuning, inserting the slug farther into the cavity results in a/an ______________ (increase/decrease) in the resonant frequency.

increase	18. While slug- and screw-tuning methods are limited to very small changes in frequency, the <u>plunger</u> method is useful when larger changes are required. The resonant frequency of a resonant cavity is proportional in all cases to the physical dimensions of the cavity.

18. (Continued)

As illustrated below, the insertion of the plunger serves to reduce the size of the cavity.



Since the resonant wavelength is directly proportional to the dimensions of the cavity, a reduction of the cavity size results in an increased resonant frequency.

The principal methods of tuning a cavity are with a __________, a __________, or a ____________.

---

screw

slug

plunger

19. Select the primary advantage of a resonant cavity.

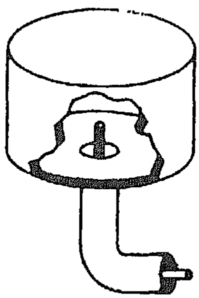
a. Extremely high Q.

b. Extremely low Q.

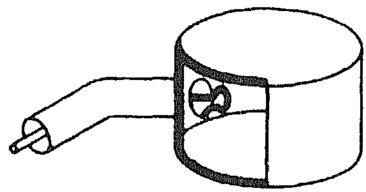
c. Higher frequency capabilities.

d. Higher resonant impedance.

be excited, but there are four common methods used in airborne microwave systems. Two methods are available for coupling a coaxial line to a cavity. The first, illustrated in figure A, involves inserting a probe into the cavity. The current flowing in the probe sets up E-lines parallel to it; and they, in turn, start oscillations.



A



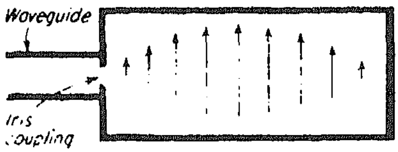
B

The second method, shown in figure B, uses a magnetic loop. The loop is placed in the region where the magnetic field will be located. The current in the loop starts an H-field in the cavity.

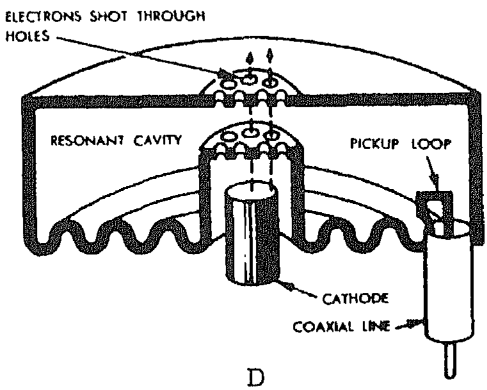
Two methods of coupling a coaxial line to a cavity are by __________ and by __________.

loop

cavity, the iris coupling shown in figure C is conveniently used. The electron-coupling method, figure D, is used to excite a ring-type cavity, often found in oscillating vacuum tubes. In this method, the energy is placed into the cavity by clouds of electrons that are virtually shot through the holes in the center of a perforated plate.



C



D

As each electron cloud goes through, it creates disturbance in the space within the cavity unt a field is set up.

Four principal methods of exciting a cavity ar

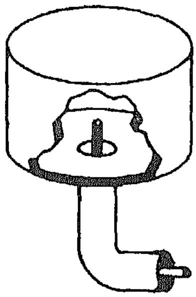
____________, _________, __________ ____________

and _____________ _________________.

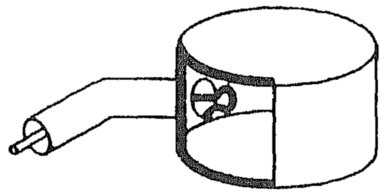
probe loop iris coupling electron coupling	22. Select the three principal methods of tuning a resonant cavity. a. Slug. b. Variable capacitance. c. Bolt. d. Screw. e. Plunger. f. Plate. g. Disc.
a. d. e.	23. State the primary advantage of a resonant cavity. 

Q.

cavity are similar to the methods for excitation: the probe, the loop, and the iris coupling are very commonly used. The probe and loop methods are used when it is necessary to couple a coaxial line to the cavity (see figures A and B). The probe intersects the E-field and sets up a voltage on the line. The loop intersects the H-field and sets up a current on the line.



A

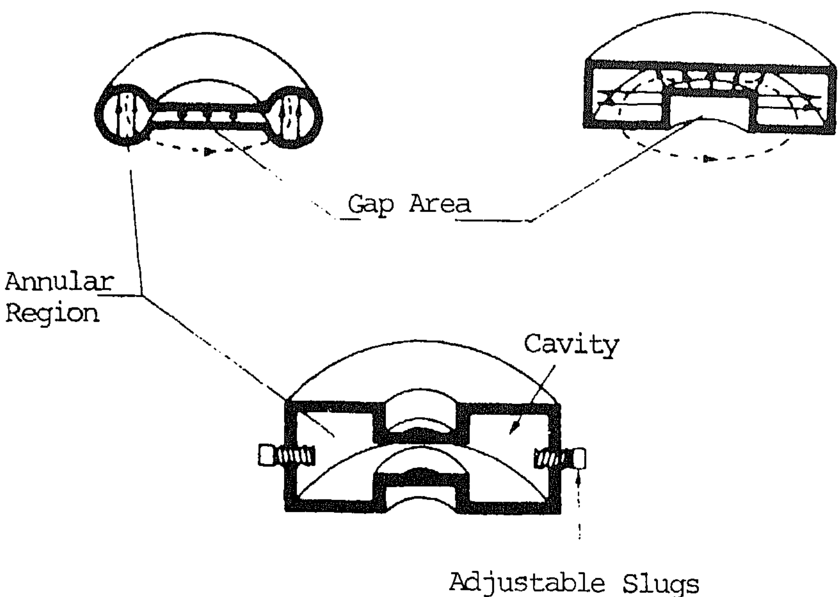


B

The iris-coupling method is used when a waveguide connection is desired. While electron coupling is used only to excite a cavity, the resultant cavity power may be removed by the probe, the loop, or the iris-coupling method.

Three principal methods of removing power from a resonant cavity are the __________, the __________, and the ________ ____________________.

probe loop iris coupling	25. Select four principal methods of exciting a resonant cavity. a. Capacitor. b. Inductor. c. Probe. d. Loop. e. Plate. f. Iris coupling. g. Electron coupling. h. Resistor.
c. d. f. g.	26. State three principal methods of tuning a resonant cavity. (1) (2) (3)
Screw. Slug. Plunger.	27. Three of the many shapes used for reentrant cavities are shown below.



The reentrant cavity is often used as the resonant element in a microwave signal source. In this application, the electron-coupling method of excitation is used by passing an electron stream through the gap area that is the actual grids of a tube.

The reentrant cavity is characterized by the following (refer to the cavities illustrated):

a. Tuning.--The gap region, containing the electric field, may be considered as the capacitive element; and the annular region, occupied by the magnetic field, may be considered the inductive element. A change in either will result in a change in resonant frequency. Often, the width of the gap area will be altered to affect a change in resonant frequency.

b. Cavity Q.--As in a conventional cavity, the Q is directly related to the ratio of the cavity volume to surface area. Since the reentrant cavity has a greater surface area, the Q is somewhat lower than that of a conventional cavity.

27. (Continued)

c. Cavity bandwidth.--Cavity bandwidth is inversely related to Q. With its lower Q, the reentrant cavity has a broader bandwidth.

Match each of the reentrant cavity characteristics listed in column A with its description listed in column B.

A	B
_____ (1) Tuning.	a. Accomplished by altering either the magnetic or the electric field.
_____ (2) Cavity Q.	b. Higher Q than that of a conventional cavity.
_____ (3) Bandwidth.	c. Broader bandwidth than that of a conventional cavity.
	d. Lower Q than that of a conventional cavity.
	e. Narrower bandwidth than that of a conventional cavity.

(1) a.
(2) d.
(3) c.

28. Select three principal methods of removing power from a resonant cavity.

a. Loop.

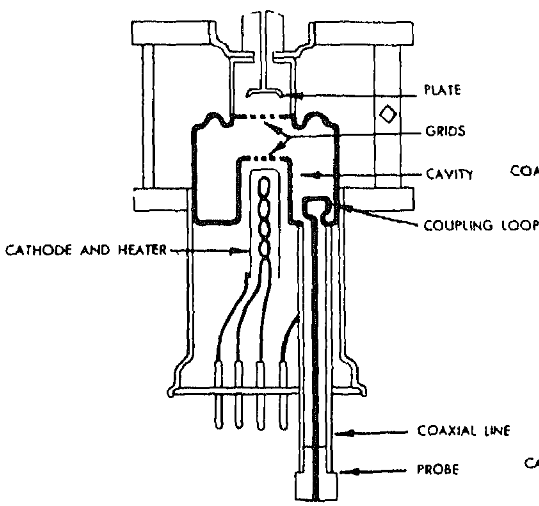
b. Plate.

c. Probe.

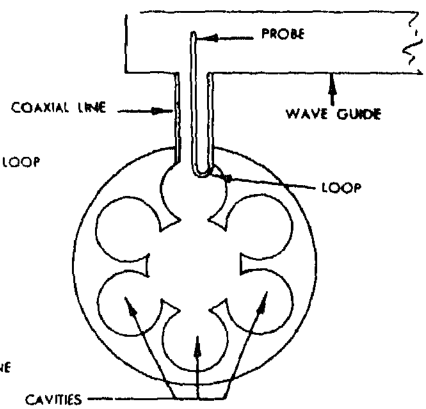
d. Disc.

e. Iris coupling.

a. c. e.	29. State four principal methods of exciting a resonant cavity. (1) (2) (3) (4)
Probe. Loop. Iris coupling. Electron coupling.	30. Resonant cavities have many applications in microwave radar. The two primary uses are as <u>resonant elements in microwave signal sources</u> and as <u>frequency meters</u>. One very common use as a resonant element in a microwave signal source occurs in klystrons and magnetrons. While these devices will be explored in greater detail in a later lesson, they are essentially resonant cavities excited by passing an electron stream through the cavity. Illustrations of a klystron and a magnetron appear in figures A and B, respectively.



A



30. (Continued)

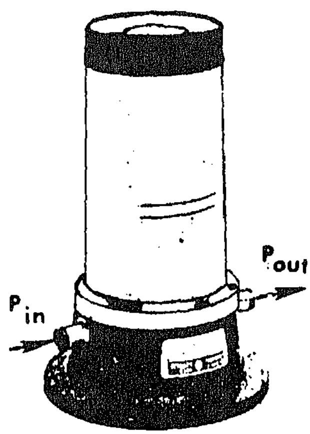
Microwave power at a specified frequency can be removed by probe or by loop coupling after the cavity is excited.

One use of resonant cavities is as _______________ _______________ in microwave signal sources.

---

resonant elements

31. When resonant cavities are used as frequency meters, the extremely high Q is used to one of its greatest advantages. With the narrow bandwidth characteristic of resonant cavities, power passes through the cavity with virtually no attenuation when the cavity is tuned off frequency. When the cavity is adjusted to the signal frequency, however, the signal power at the output is sharply reduced. Special techniques in the construction of plunger tuning provide frequency-measurement accuracy in the order of 0.07 percent. Shown below is a commercial frequency meter.



Select two primary uses of resonant cavities.

a. Resonant elements in microwave signal sources.

b. Filter circuits.

c. Frequency meters.

d. Digital voltmeters.

e. Slotted lines.

---

a.

c.

32. Match each of the reentrant cavity characteristics listed in column A with its description listed in column B.

A	B
_____ (1) Tuning.	a. Broader bandwidth than that of a conventional cavity.
_____ (2) Cavity Q.	b. Lower Q than that of a conventional cavity.
_____ (3) Bandwidth.	c. Narrower bandwith than that of a conventional cavity.
	d. Higher Q than that of a conventional cavity.
	e. Accomplished by altering either the magnetic or the electric field.

(1) e. (2) b. (3) a.	33. State three principal methods of removing power from a resonant cavity. (1) (2) (3)
Probe. Loop. Iris coupling.	34. Select two primary uses of resonant cavities. a. Frequency meters. b. Digital voltmeters. c. Slotted lines. d. Filter circuits. e. Resonant elements in microwave signal sources.
a. e.	35. Match each of the reentrant cavity characteristics listed in column A with its description listed in column B.

A	B
_____ (1) Tuning.	a. Narrower bandwidth than that of a conventional cavity.
_____ (2) Cavity Q.	b. Higher Q than that of a conventional cavity.
_____ (3) Bandwidth.	c. Accomplished by altering either the magnetic or the electric field.
	d. Lower Q than that of a conventional cavity.
	e. Broader bandwidth than that of a conventional cavity.

a. Slotted lines.

b. Frequency meters.

c. Microwave antennas.

d. Digital voltmeters.

e. Resonant elements in microwave signal sources.

You have completed this program. Review the objectives on page i. If you do not completely understand an objective, turn to the frame/s indicated by the number/s in parentheses.

REFERENCES:

1. Introduction to Microwave Theory and Measurements, Lance, McGraw-Hill, 1964, Chapter 9, pp. 148-166.
2. Electronic Circuit Analysis, NAVWEPS 00-80T-79, Vol. II, 1963, Chapter 11, pp. 11-34 through 11-40.
3. Electronic and Radio Engineering, Terman, McGraw-Hill, Fourth Edition, Chapter 5, pp. 158-165.
4. Aviation Electronics Technician 1 and C, NAVPERS 10318-C, Chapter 12, pp. 279-282.

RESONANT CAVITIES

REVIEW TEST

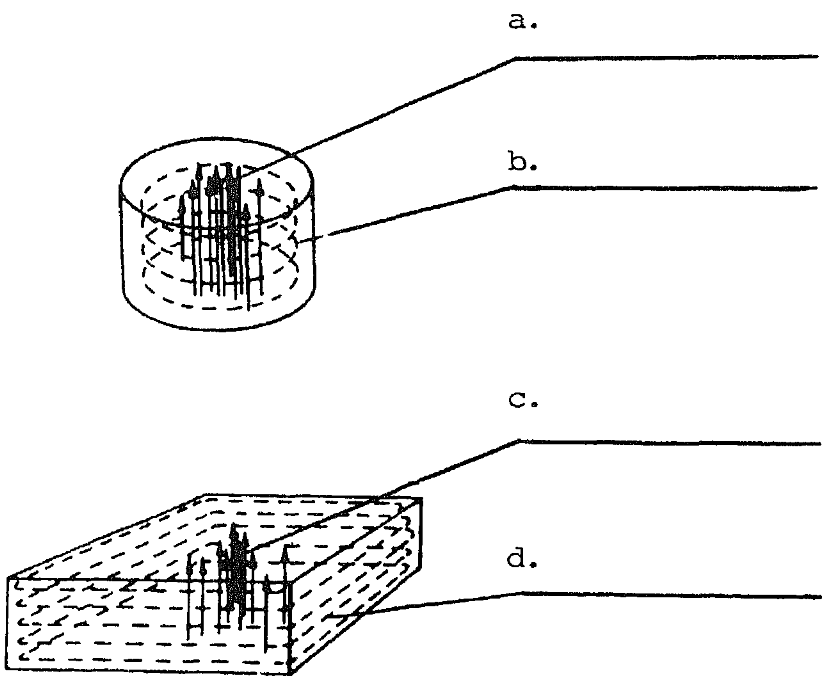
1. List the two general types of resonant cavities.

   (1)

   (2)

2. State the definition of the dominant mode of a resonant cavity.

3. Label the electric field and the magnetic field on each of the two resonant cavities shown below.



dominant mode listed in column B.

A	B
_____ (1) Rectangular.	a. TE_{101}.
_____ (2) Cylindrical.	b. TM_{010}.
	c. TM_{111}.
	d. TE_{100}.

5. State the primary advantage of a resonant cavity.

6. State three principal methods of tuning a resonant cavity.

   (1)

   (2)

   (3)

7. State four principal methods of exciting a resonant cavity.

   (1)

   (2)

   (3)

   (4)

8. State three principal methods of removing power from a resonant cavity.

   (1)

   (2)

   (3)

9. Match each of the reentrant resonant cavity characteristics listed in column A with its description listed in column B.

A	B
_____ (1) Tuning.	a. Accomplished by altering either the magnetic or the electric field.
_____ (2) Cavity Q.	b. Higher Q than that of a conventional cavity.
_____ (3) Bandwidth.	c. Broader bandwidth than that of a conventional cavity.
	d. Lower Q than that of a conventional cavity.
	e. Narrower bandwidth than that of a conventional cavity.

0. Select two primary uses of resonant cavities.

a. Resonant elements in microwave signal sources.

b. Digital voltmeters.

c. Slotted lines.

d. Frequency meters.

e. Microwave antennas.

ANSWERS TO REVIEW TEST

1. Rectangular.

   Cylindrical.

2. The lowest resonant frequency associated with the cavity.

3. a. Electric

   b. Magnetic

   c. Electric.

   d. Magnetic.

4. (1) a.

   (2) b.

5. Extremely high Q.

6. Screw.

   Slug.

   Plunger.

7. Probe.

   Loop.

   Iris coupling.

   Electron coupling

8. Probe.

   Loop.

   Iris coupling.

9. (1) a.
   (2) d.
   (3) c.

10. a.

    d.